Thinking about numbers: Mathematical models and the control of HIV

Brian Williams

WRHI, Johannesburg and SACEMA, Stellenbosch, South Africa

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The purpose of models is not to fit the data but to sharpen the question. Karlin, S.

Modelling for modellers

- Stay as close to the data as you can
- Put in as much biology as you can
- Keep it simple

Modelling for non-modellers

- Examine the data carefully
- Question all the assumptions
- Assume that the modellers know what they are doing

The case reproduction number

R_0

The number of secondary cases you get from one primary case of infection

Why is R_0 so important?

1. It tells us if things are getting better or worse
   $R_0 > 1$: prevalence increases exponentially
   $R_0 < 1$: prevalence falls exponentially

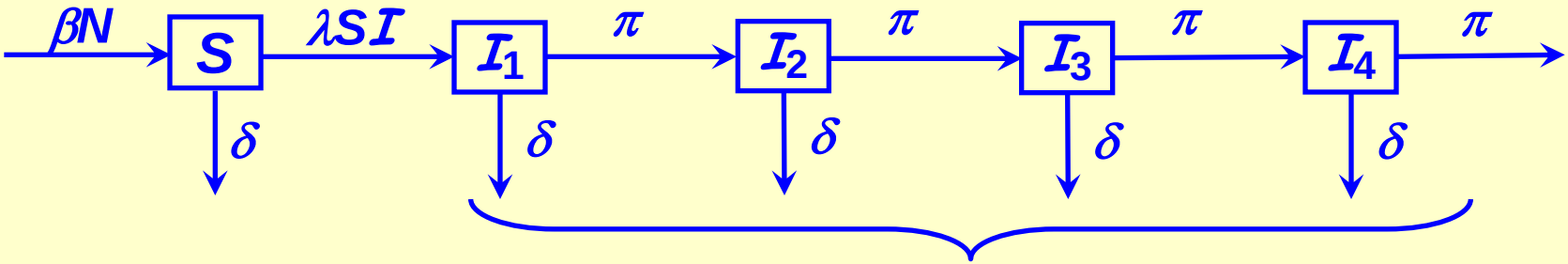
2. It tells us the magnitude of the control problem. If we reduce transmission by a factor of R_0 we will eventually eliminate the disease.

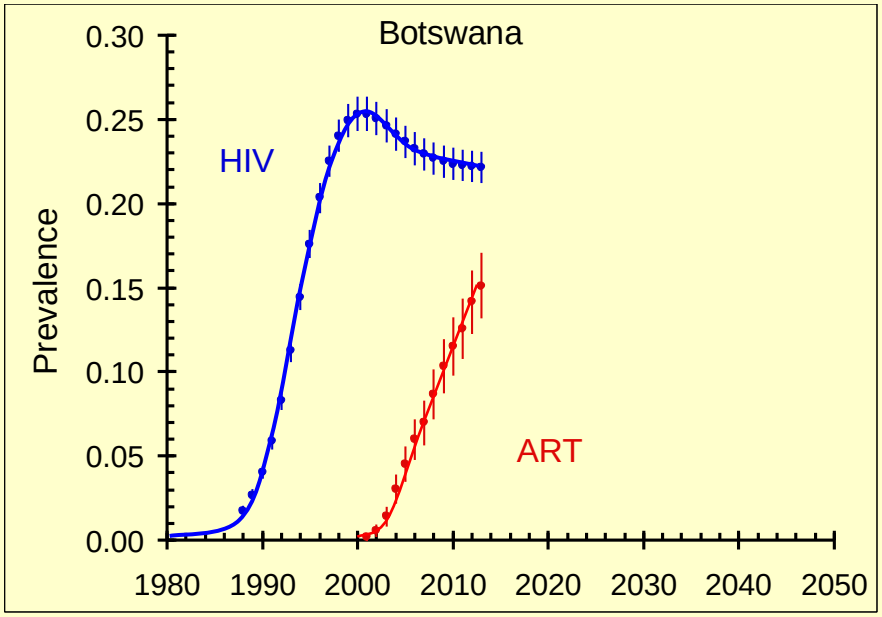
3. It tells us the expected prevalence if we do nothing and the vaccination coverage needed for elimination

$$P = (R_0 - 1)/ R_0$$

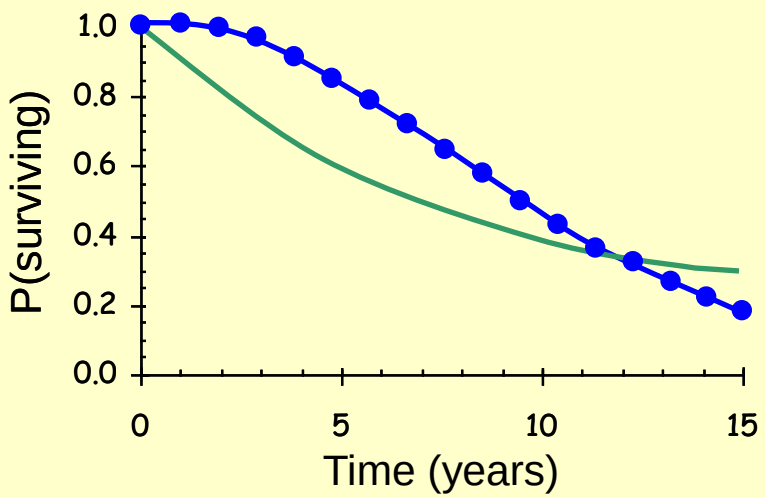
http://en.wikipedia.org/wiki/Basic_reproduction_number

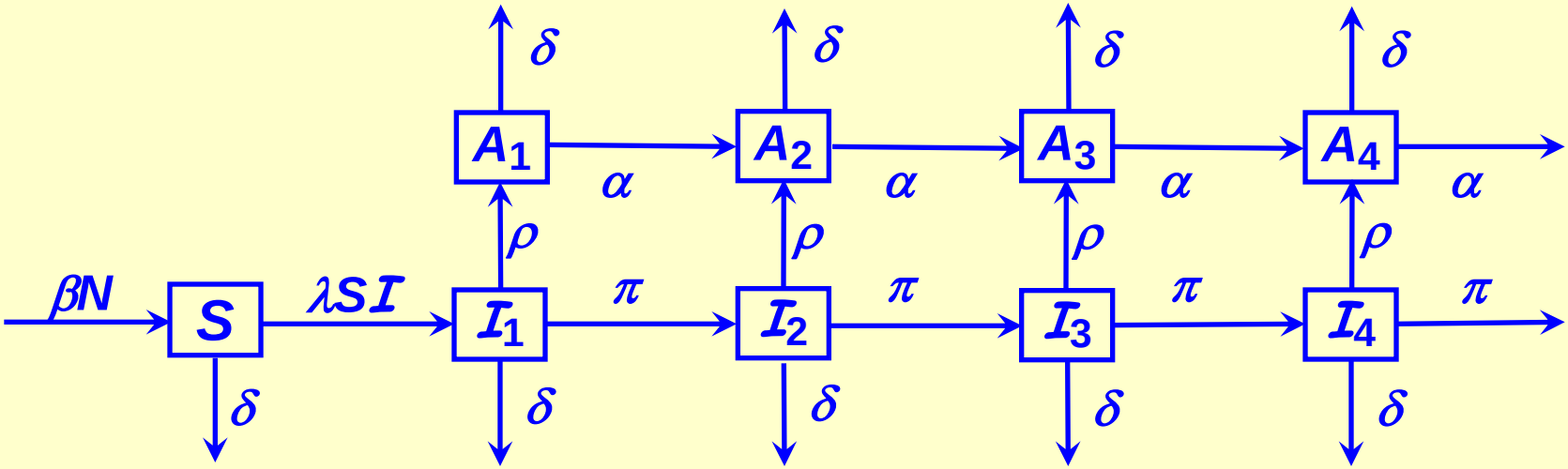
HIV in Botswana
Trends, estimates and projections

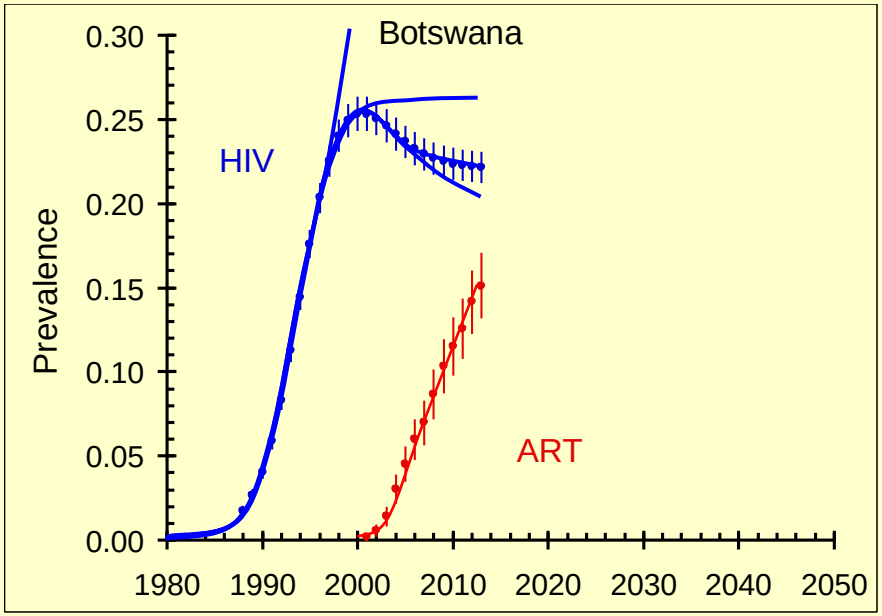




4 stages of infection to get the right survival







Doubling time ≈ 1.5 yrs

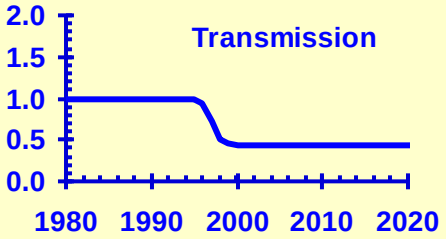
Life expectancy ≈ 10 yrs

$R_0 \approx 10/1.5 \approx 7$

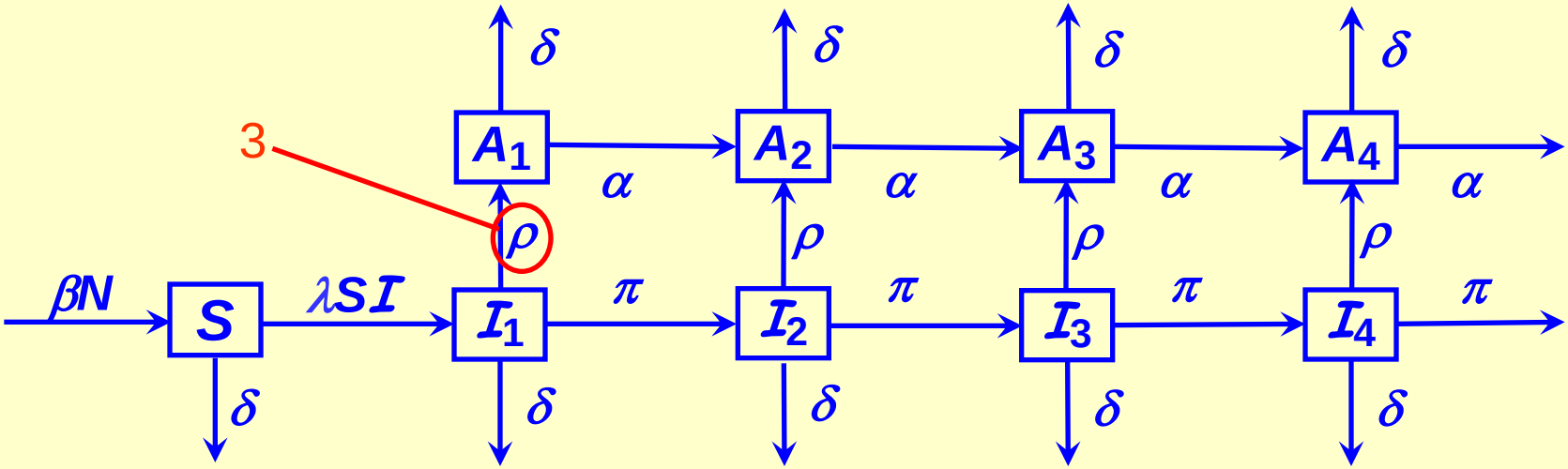
Heterogeneity in risk

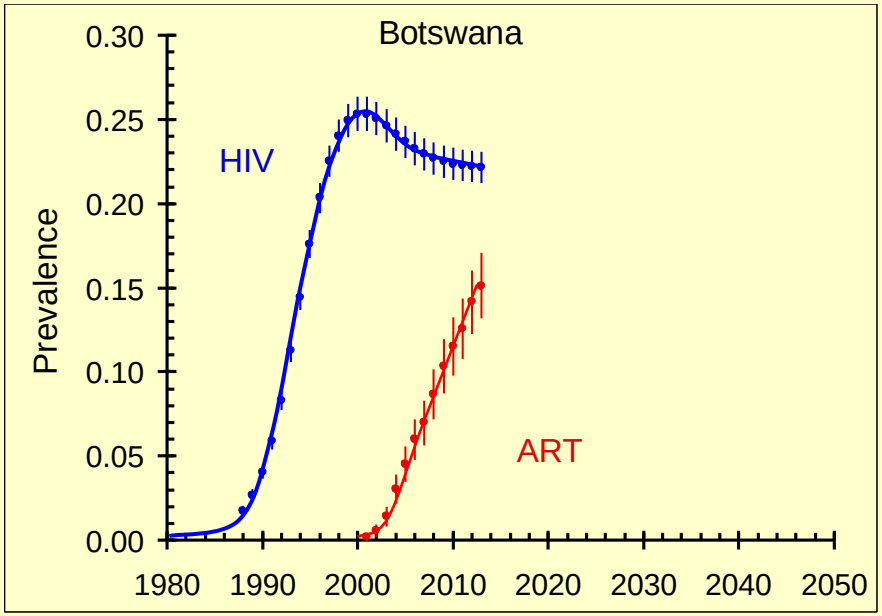
$$\lambda \rightarrow \lambda\left(1-\frac{P}{P^*}\right)$$

Change in behaviour



Anti-retroviral therapy





Initial prevalence

Doubling time ≈ 1.5 yrs

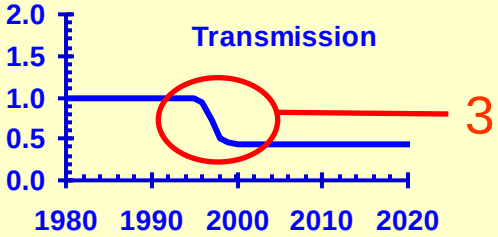
Life expectancy ≈ 10 yrs

$R_0 \approx 10/1.5 \approx 7$

Heterogeneity in risk

$$\lambda \rightarrow \lambda\left(1-\frac{P}{P^*}\right)$$

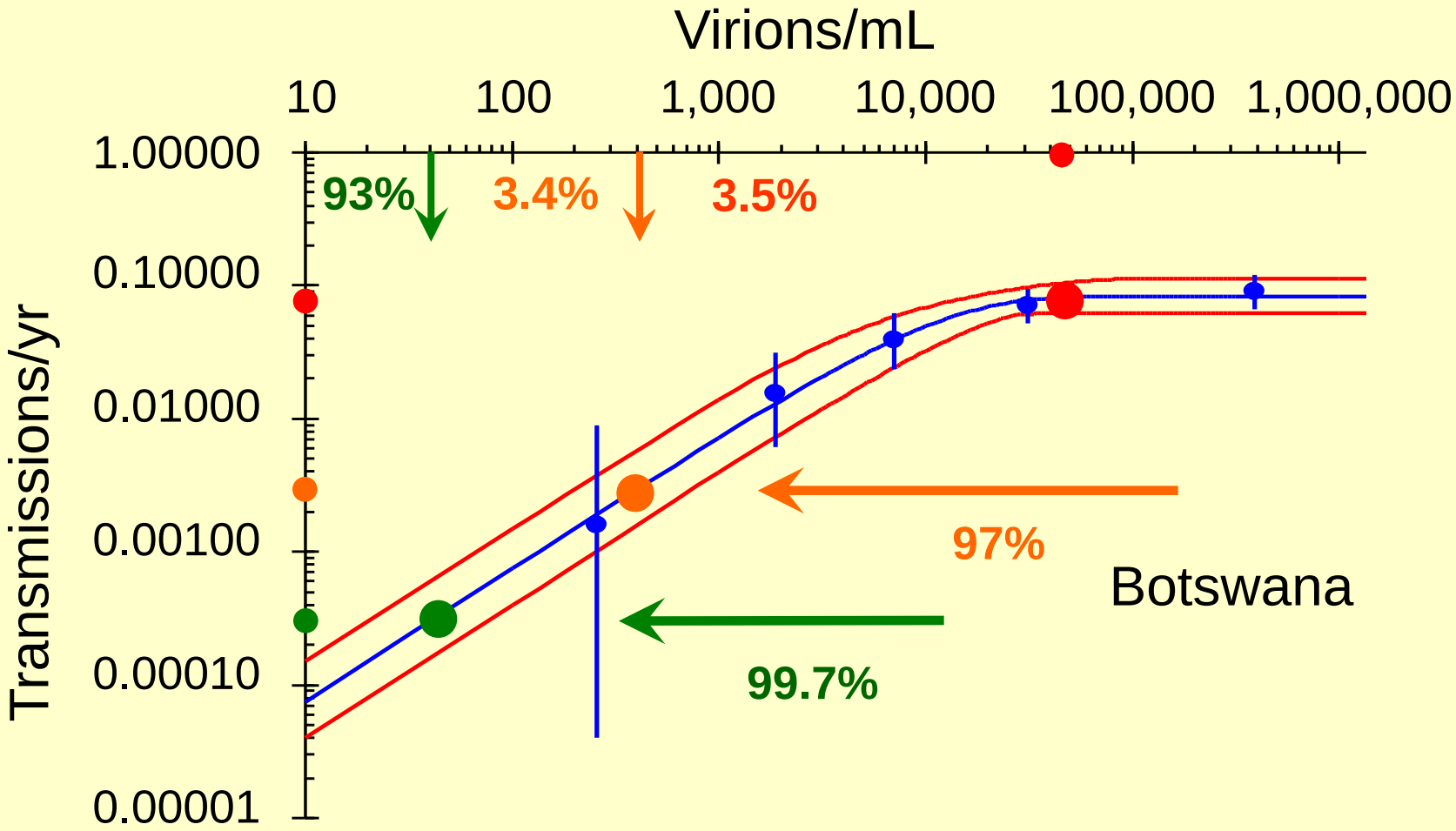
Change in behaviour



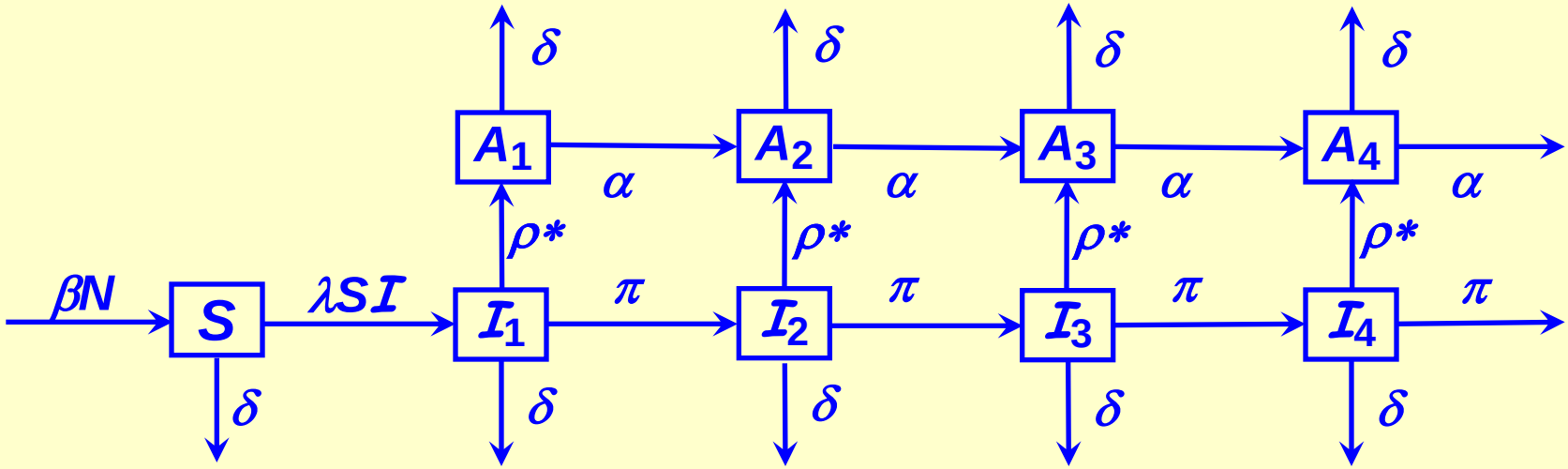
Anti-retroviral therapy

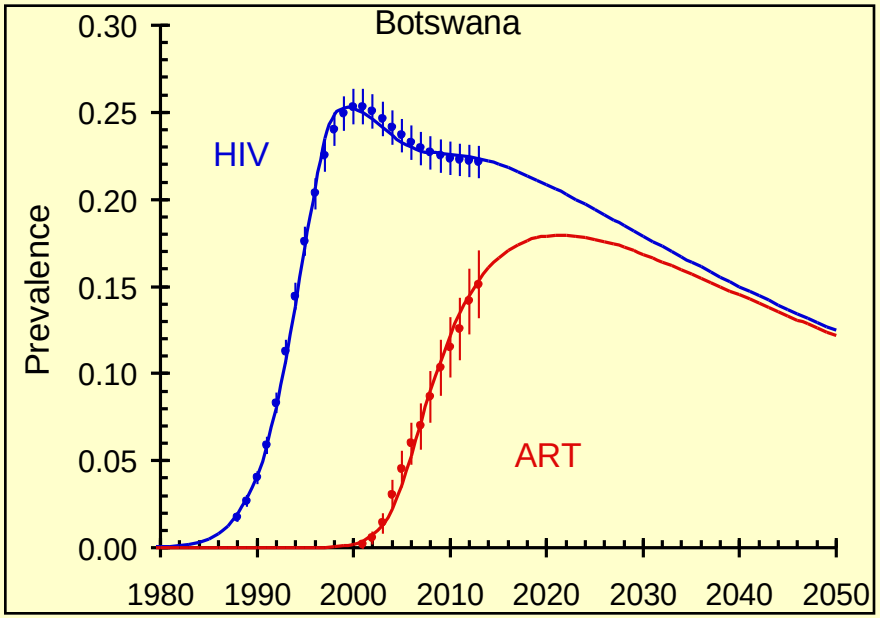
How infectious are people on ART?

Viral load and transmission

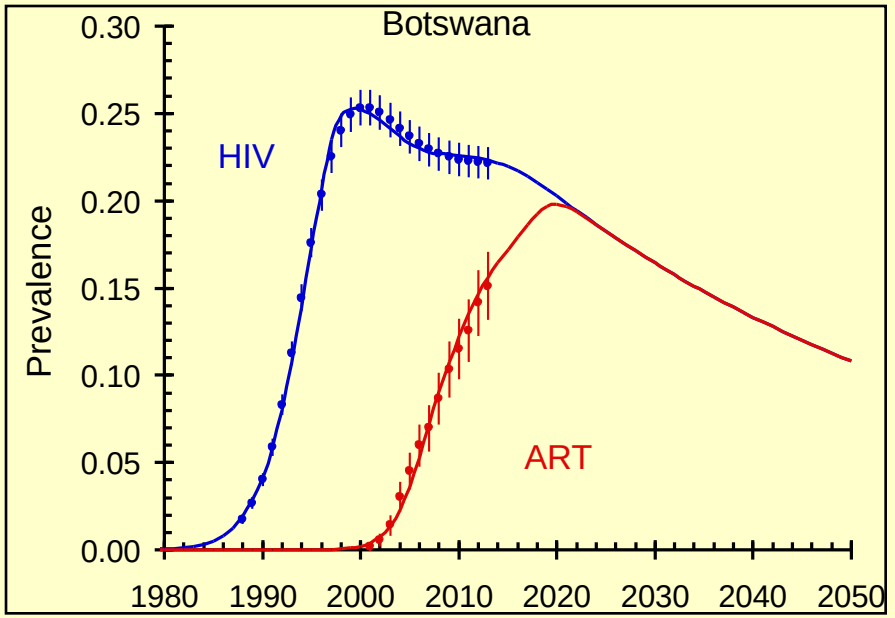


Attia 2009 AIDS; Gaolathe 2016 Lancet

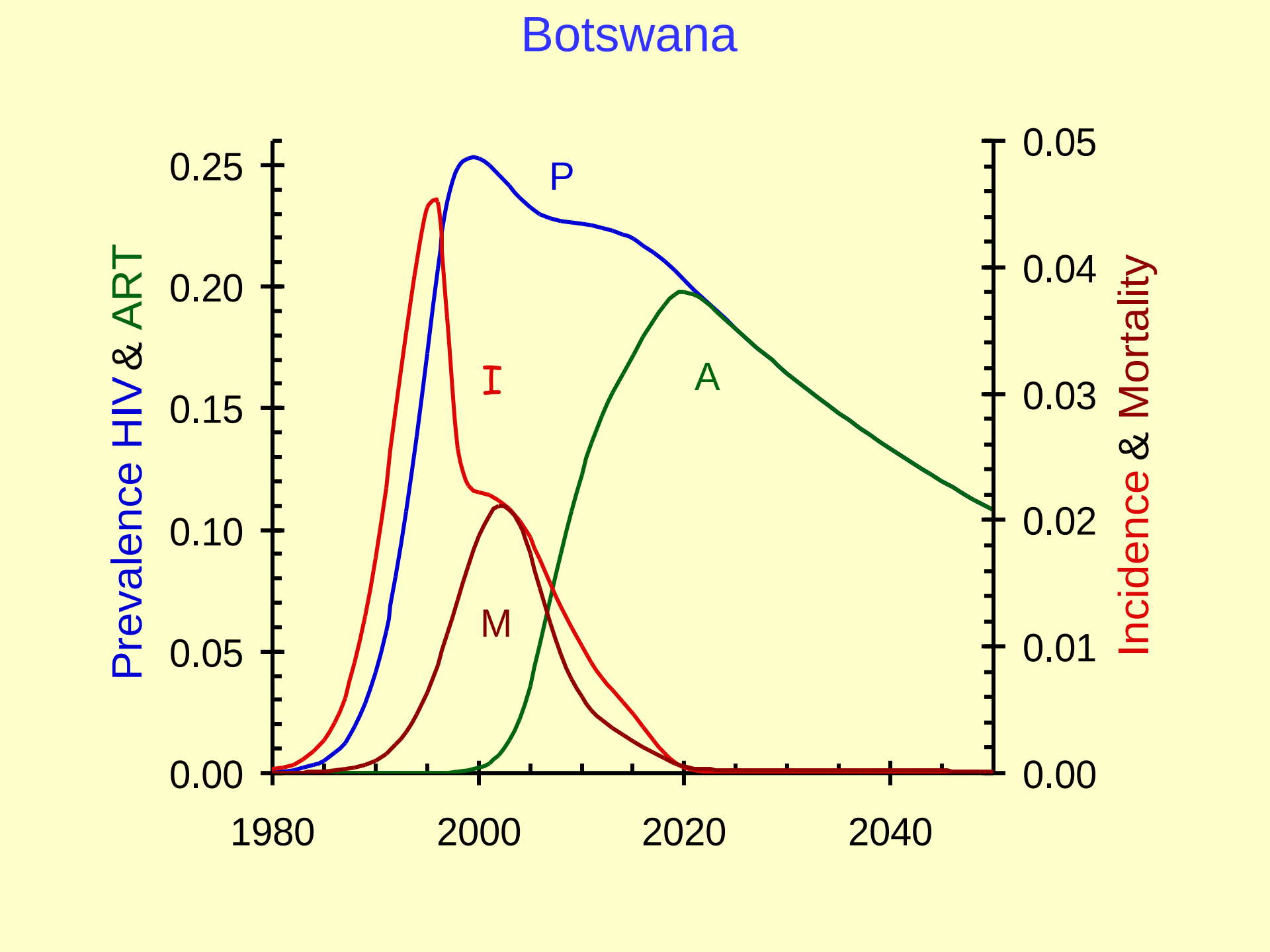




Constant effort

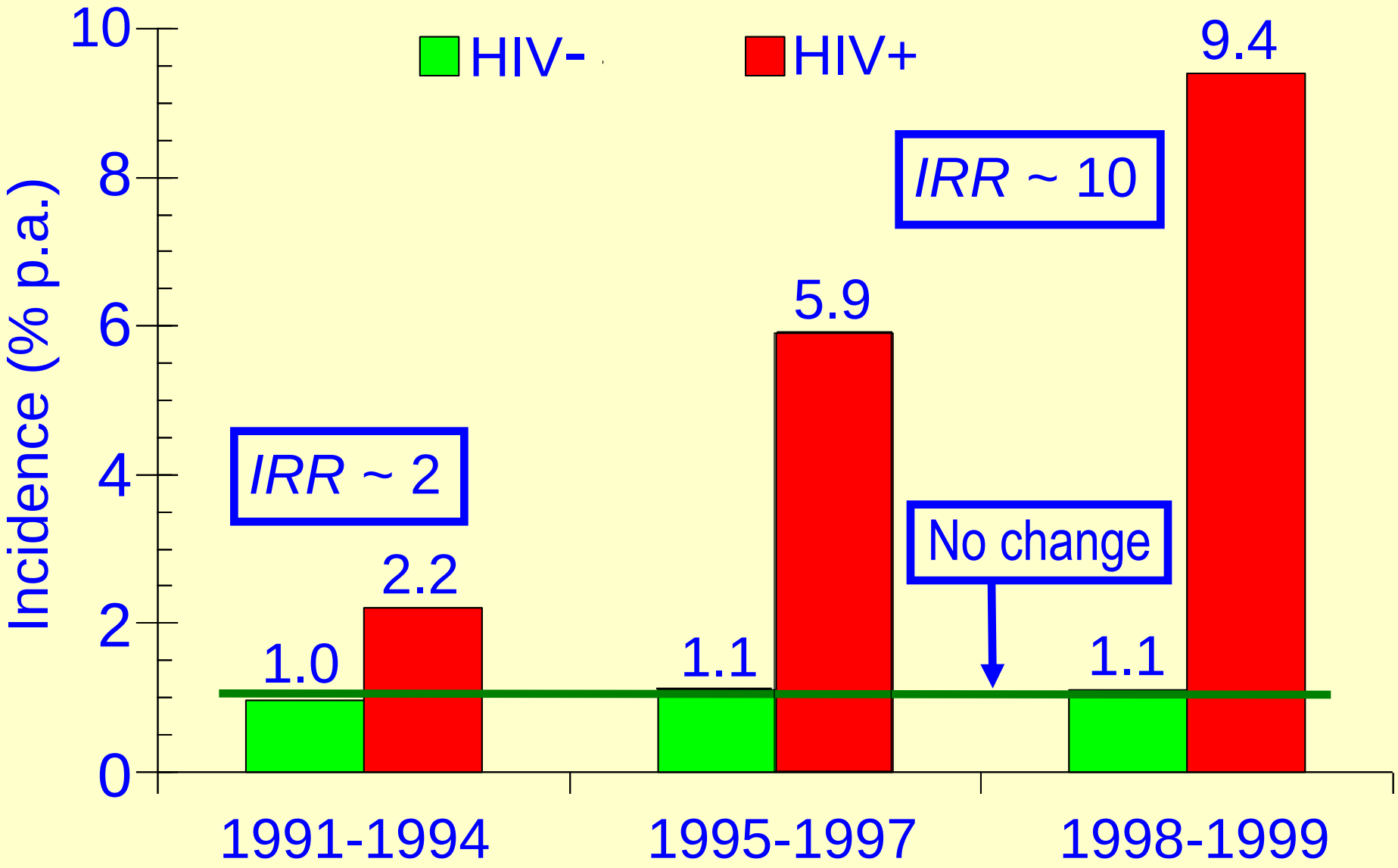


90-90-90 + Prevention


Botswana
Prevalence HIV & ART
Incidence & Mortality
0.25
0.20
0.15
0.10
0.05
0.00
0.05
0.04
0.03
0.02
0.01
0.00
1980
2000
2020
2040
P
I
A
M

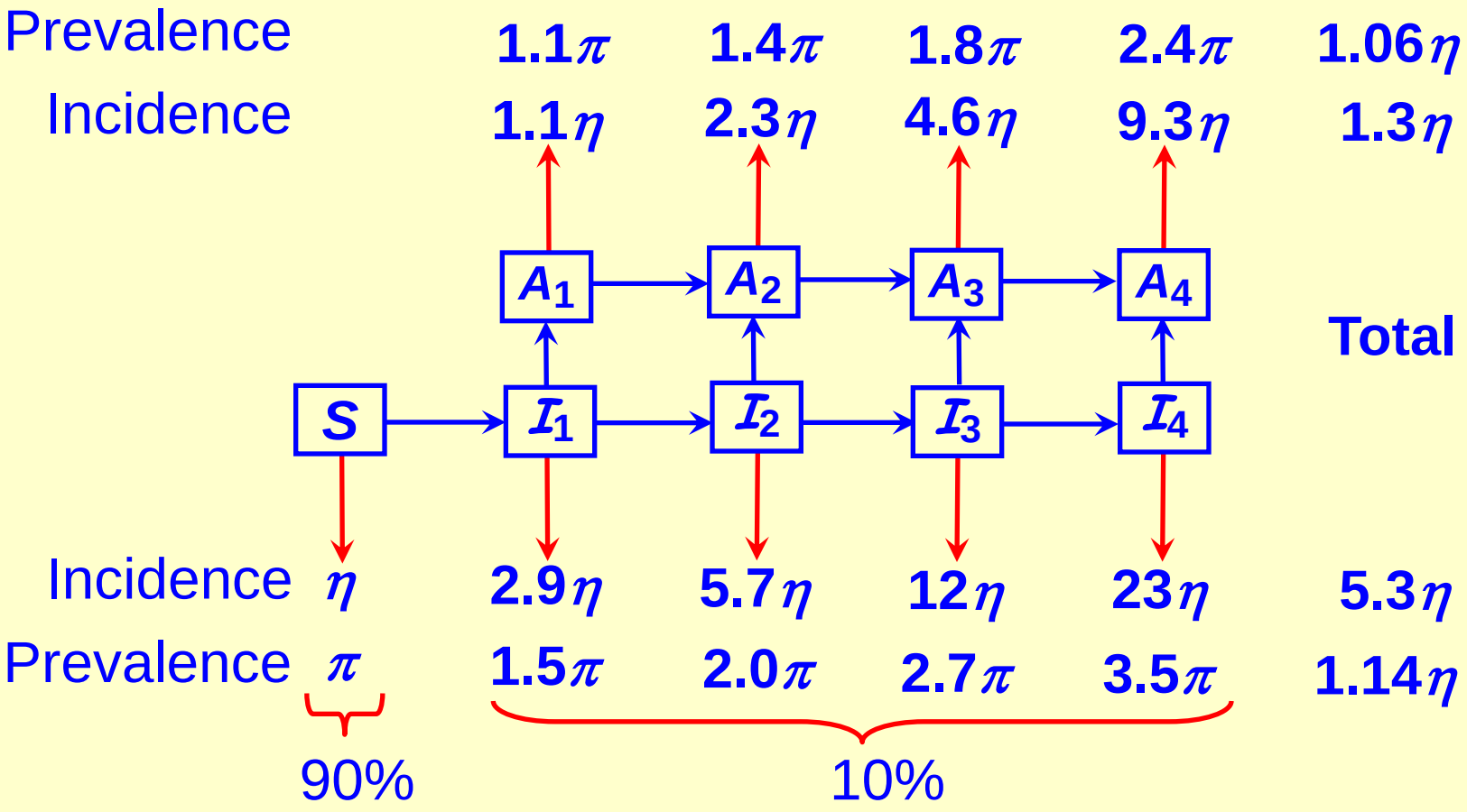
What does HIV do to TB?

TB and HIV: Gold Miners in South Africa



Corbett *et al. Journal of Infectious Diseases* 2003; 188: 1156-63

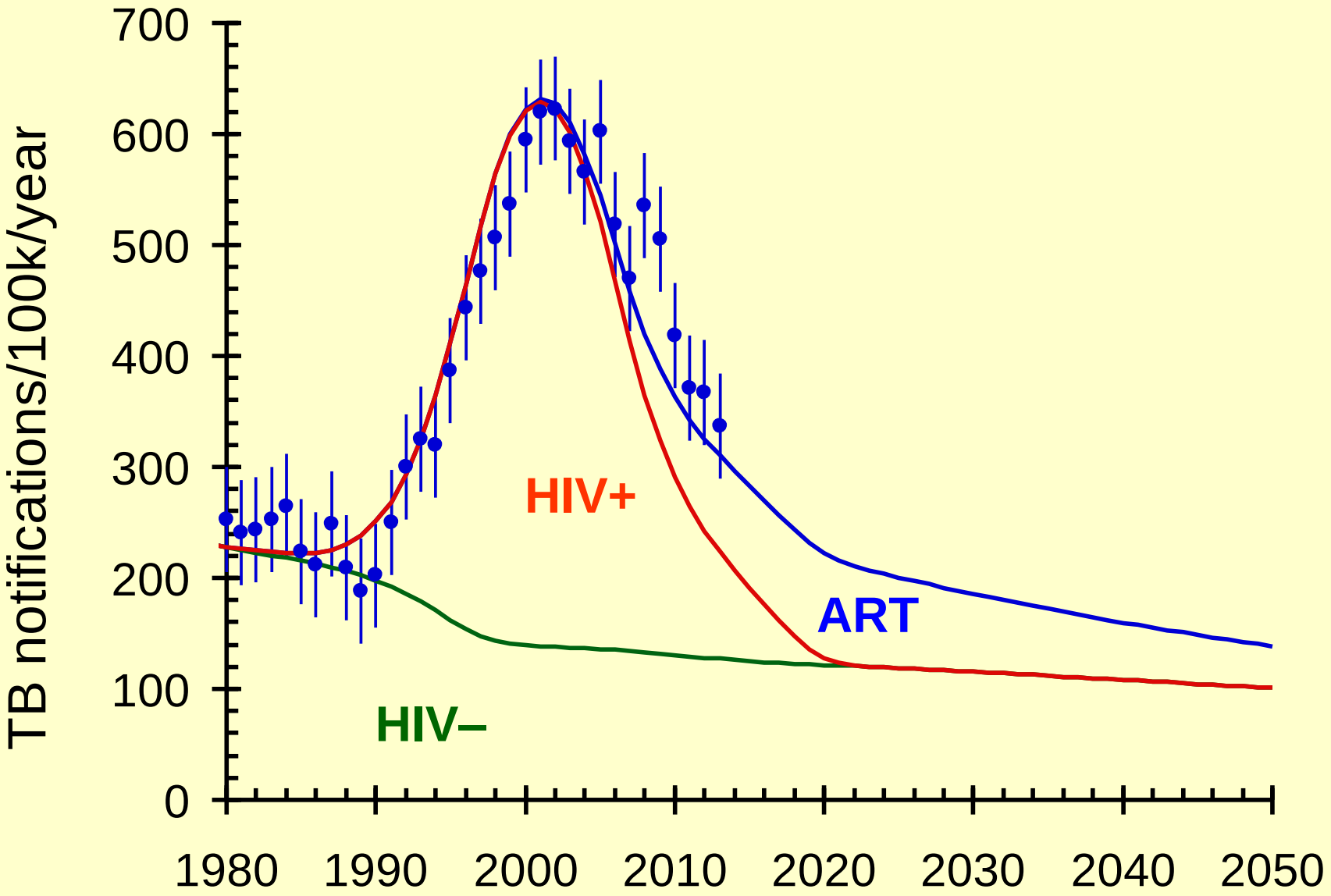
Impact of HIV and ART on TB



Three variable parameters: Incidence pre-HIV, rate of increase with HIV-progression, reduction in disease duration

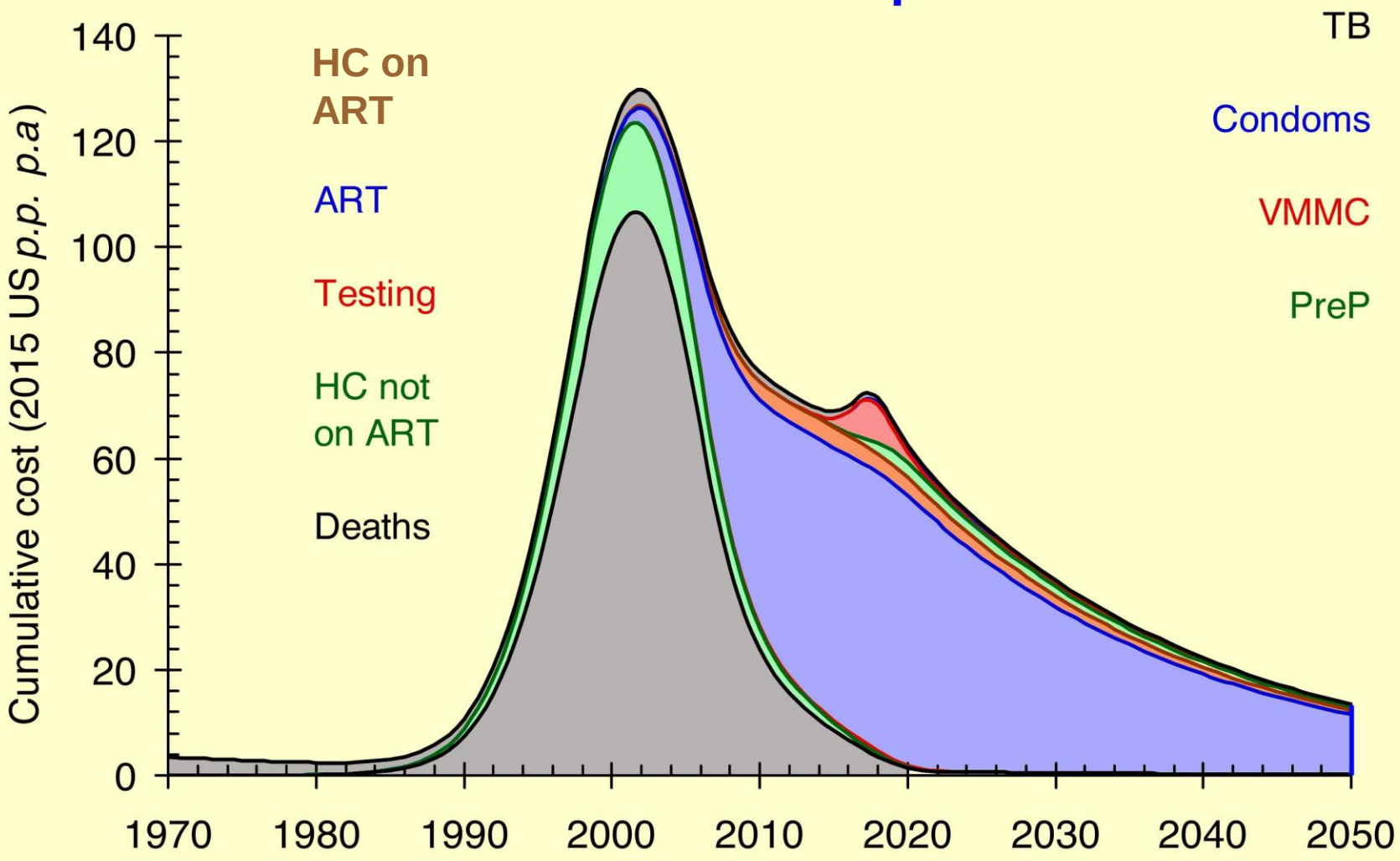
Botswana

TB


TB notifications/100k/year
700
600
500
400
300
200
100
0
1980
1990
2000
2010
2020
2030
2040
2050
HIV+
ART
HIV–

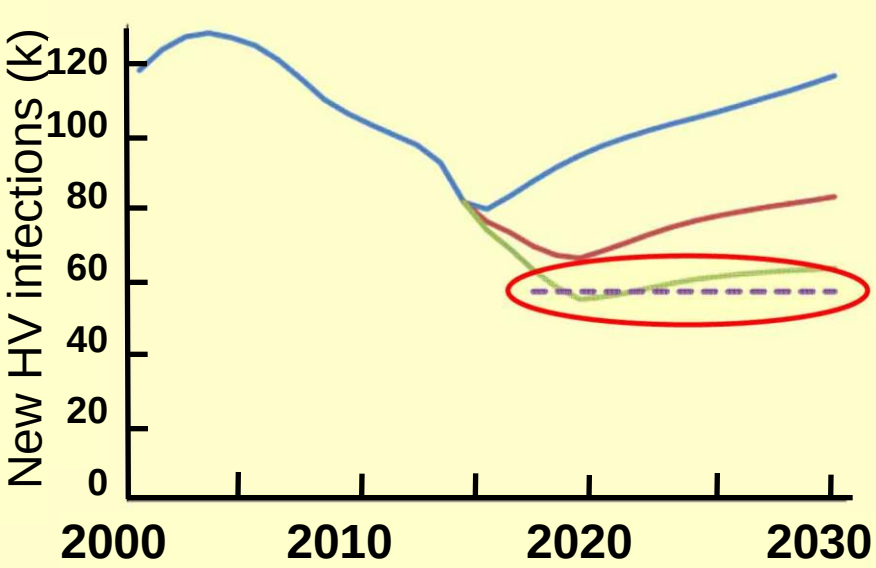
Botswana

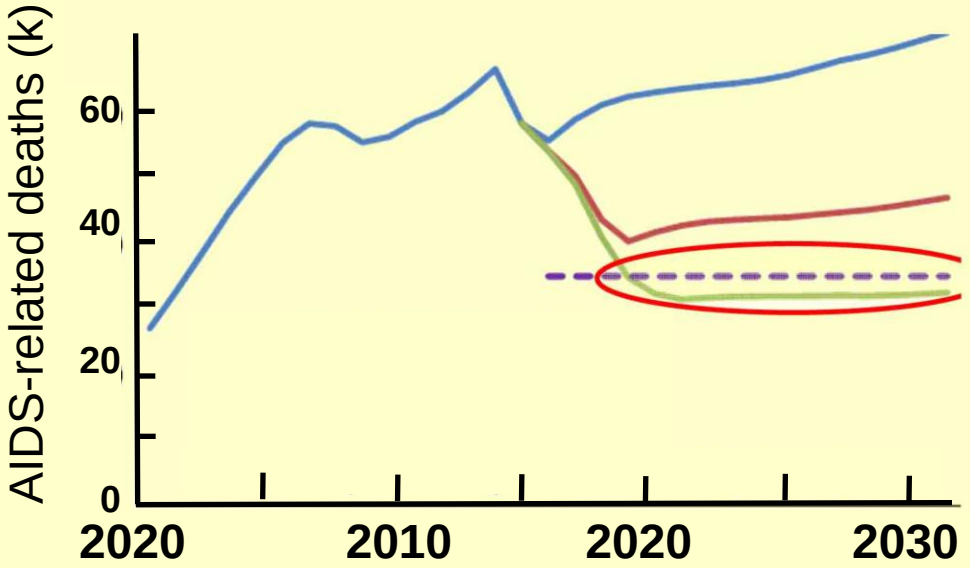
Cost of treatment and prevention



US$1.5 Bn 2016 to 2030 or US$150 M *p.a.*

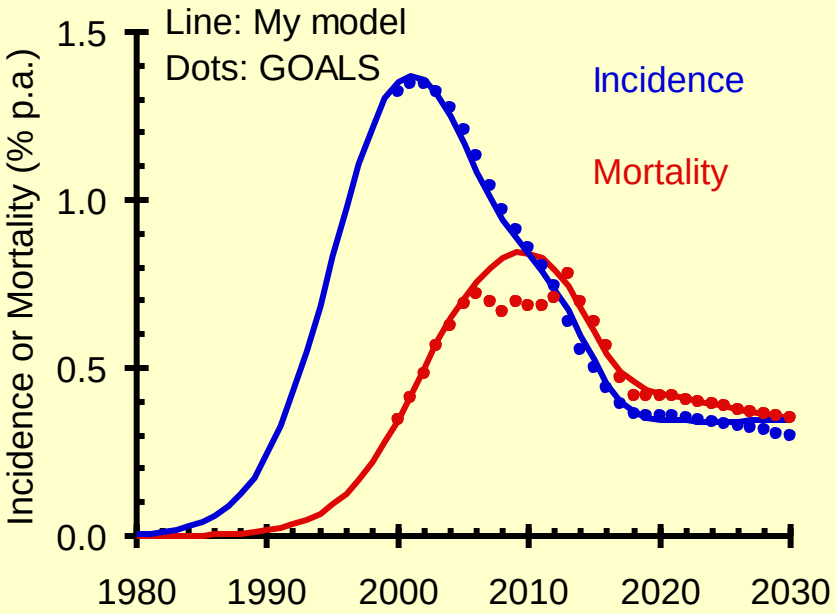
Impact of treatment and prevention in Mozambique





Constant coverage Current targets Accelerated scale-up

GOALS model ART
50% coverage
20% as infectious



My model ART
65% coverage
35% as infectious

Korenromp et al. PLOS 2015

Thank you